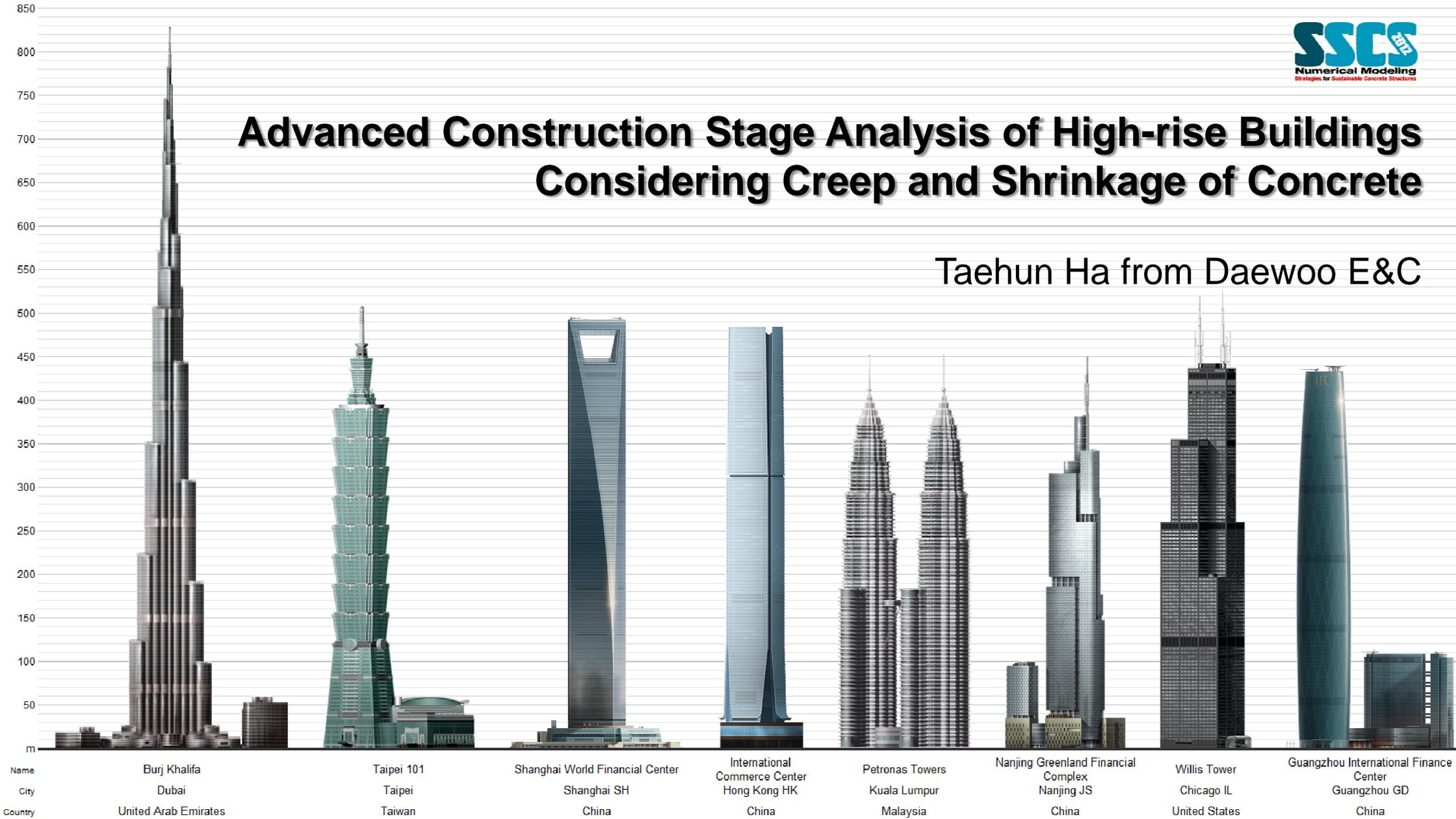
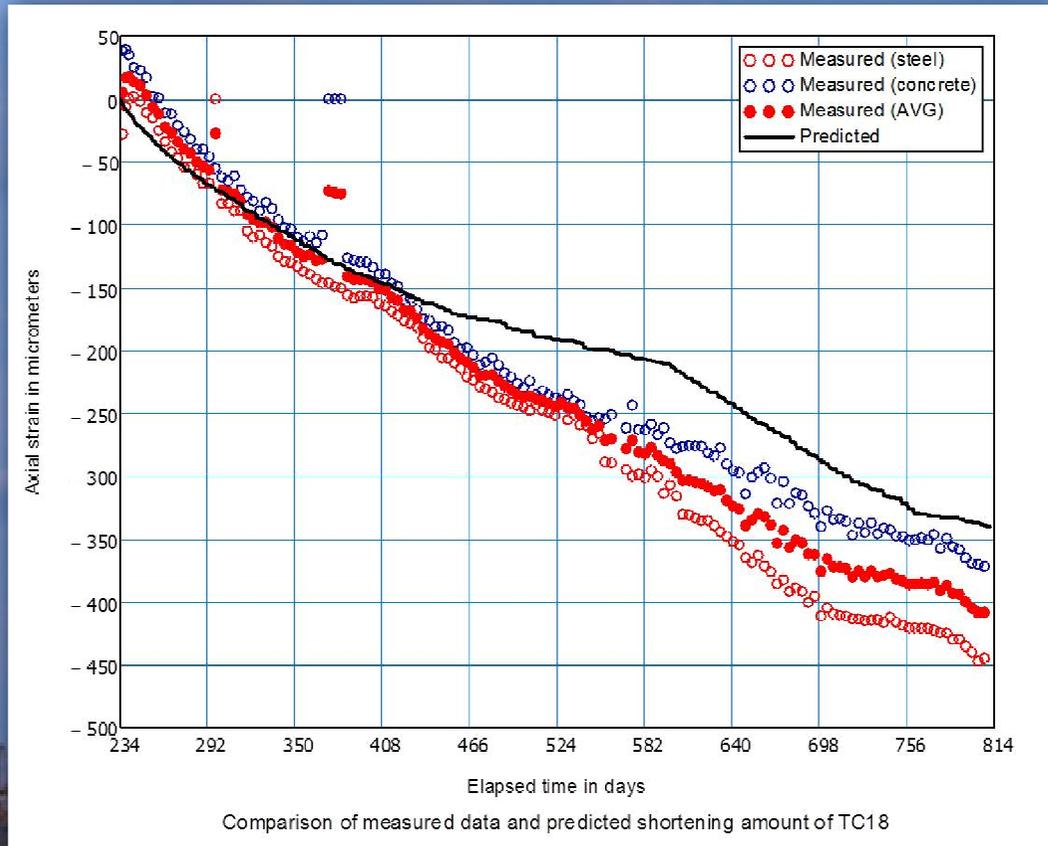


Advanced Construction Stage Analysis of High-rise Buildings Considering Creep and Shrinkage of Concrete

Taehun Ha from Daewoo E&C



NEATT in Incheon Korea

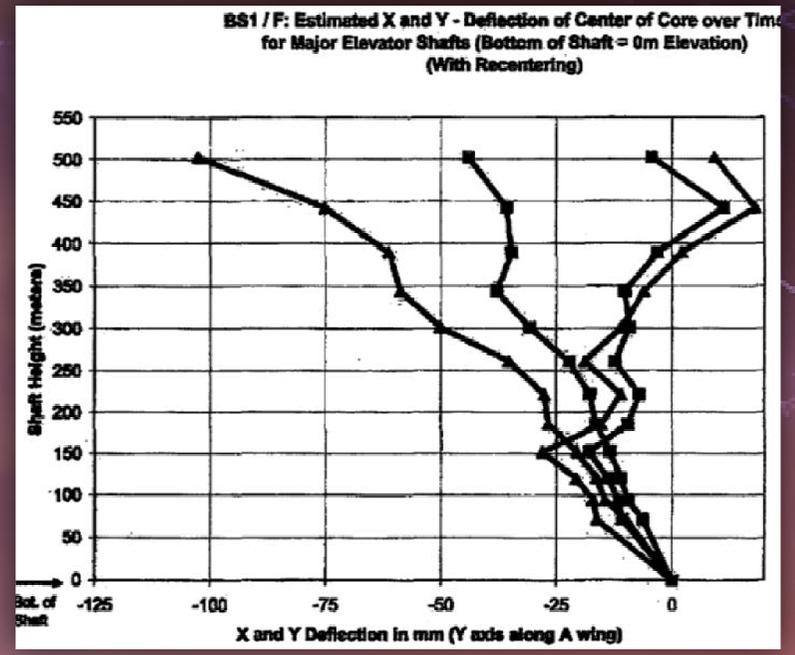
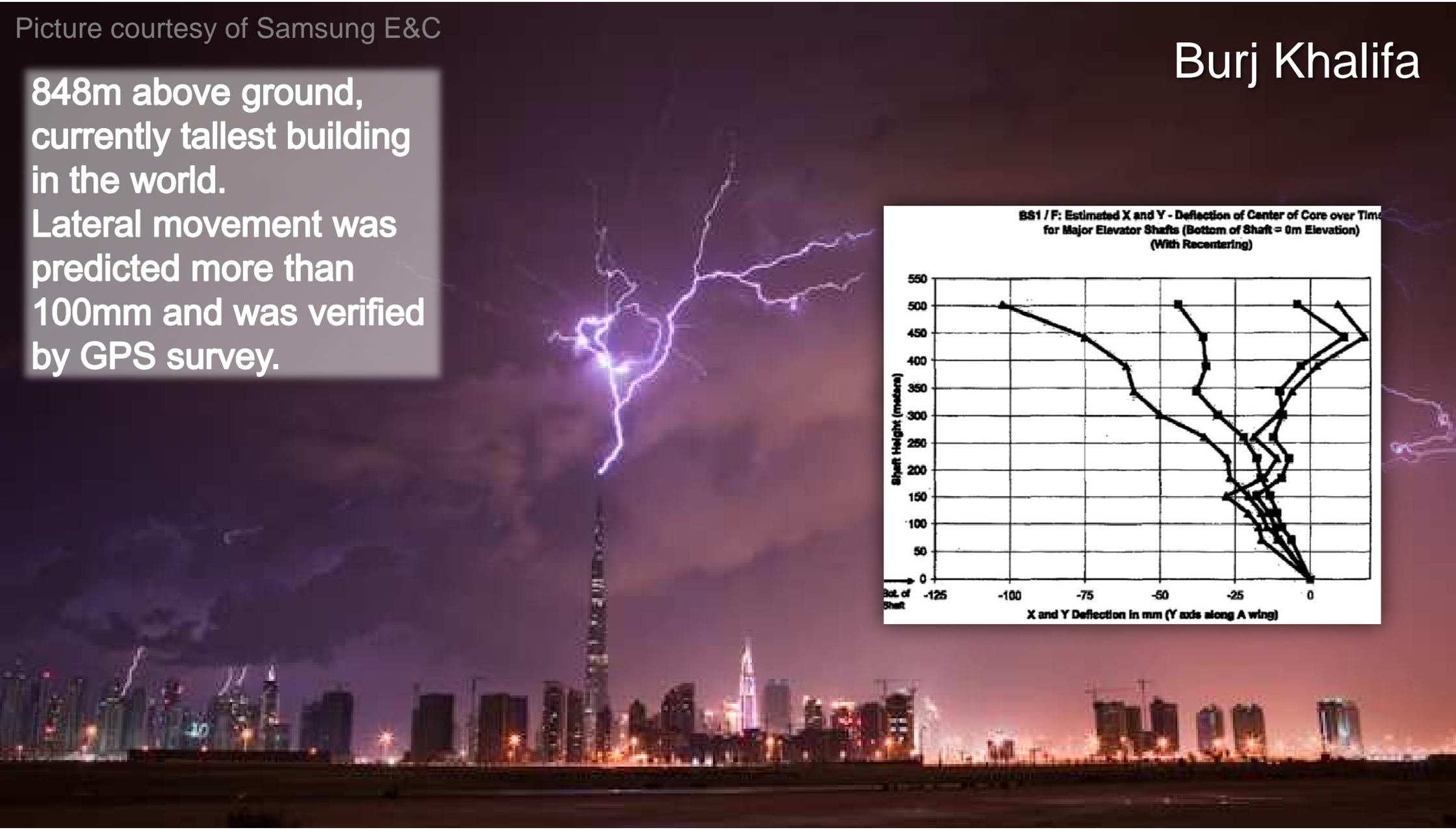


**305m above ground, currently tallest building in South Korea.
Axial shortening was predicted more than 200mm and was verified in field monitoring.**

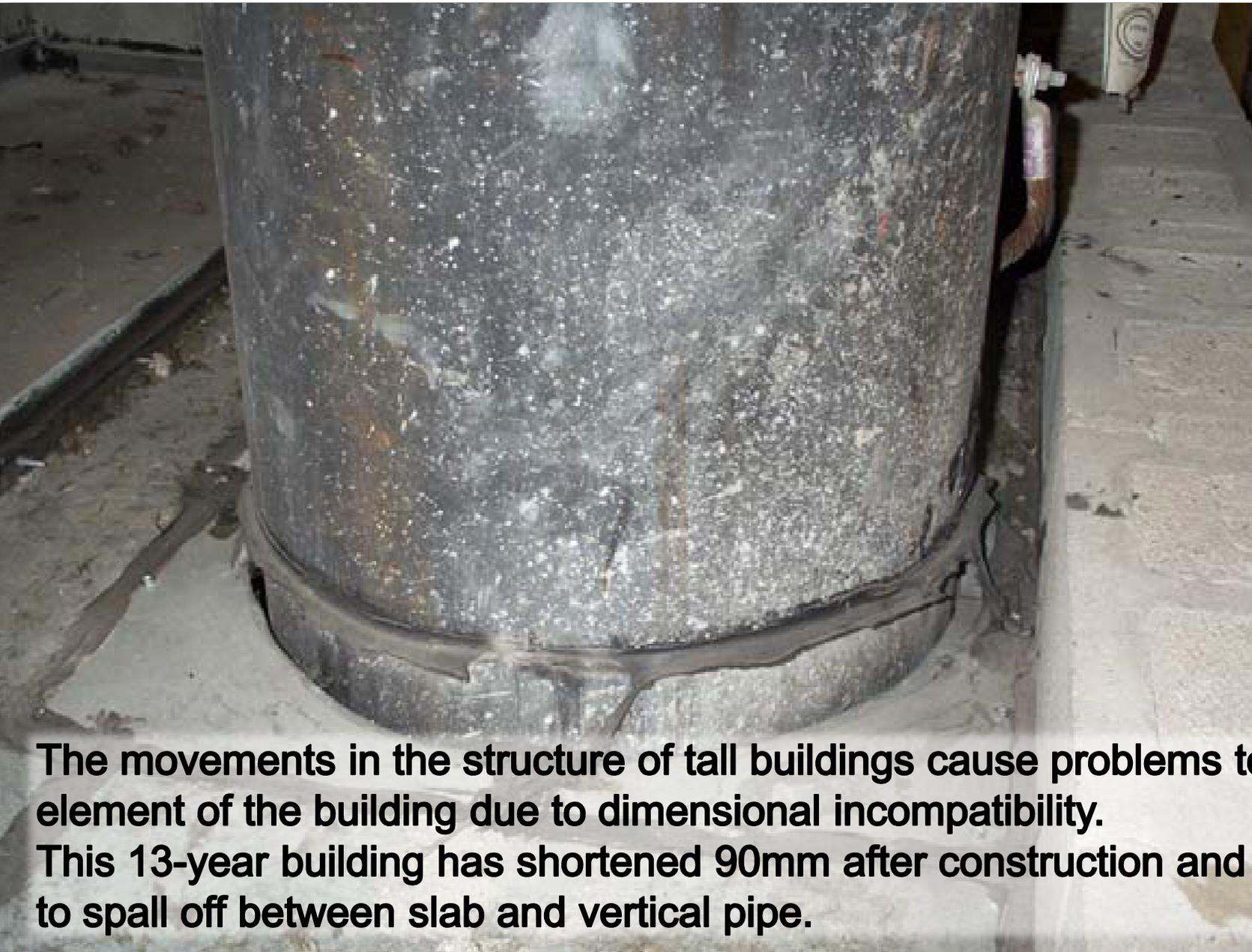
Picture courtesy of Samsung E&C

848m above ground,
currently tallest building
in the world.
Lateral movement was
predicted more than
100mm and was verified
by GPS survey.

Burj Khalifa



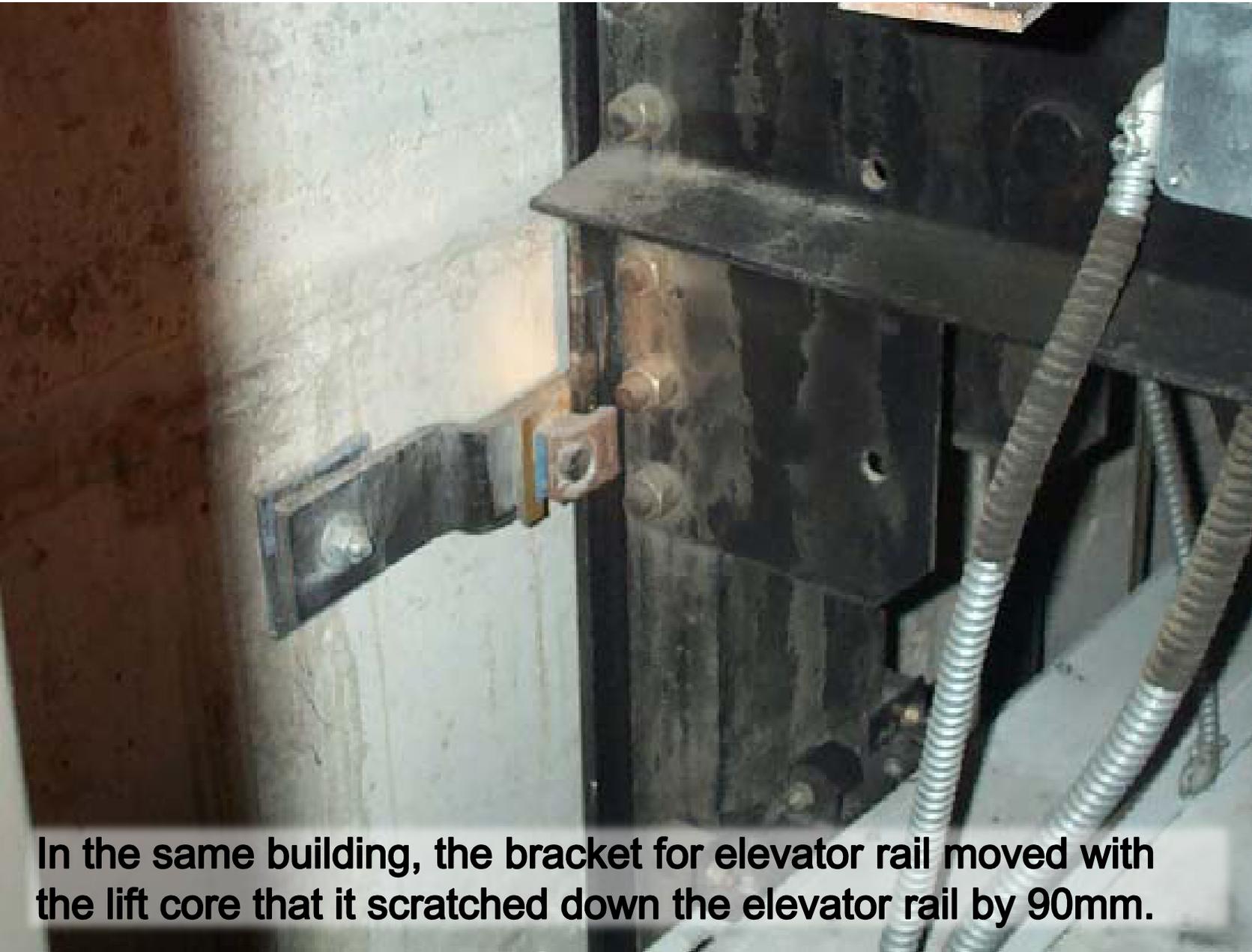
Problems



The movements in the structure of tall buildings cause problems to non-structural element of the building due to dimensional incompatibility. This 13-year building has shortened 90mm after construction and causes the sealing to spall off between slab and vertical pipe.



Problems



In the same building, the bracket for elevator rail moved with the lift core that it scratched down the elevator rail by 90mm.



Problems



The confined differential shortening on both sides of this deep beam caused critical diagonal cracking after construction.





Solutions

at Design

- Member section
- Material selection

during Construction

- Adjustment or delay joint
- Design or material change
- Structure preset or compensation (**last resort**)



Building Movement Control

Monitoring

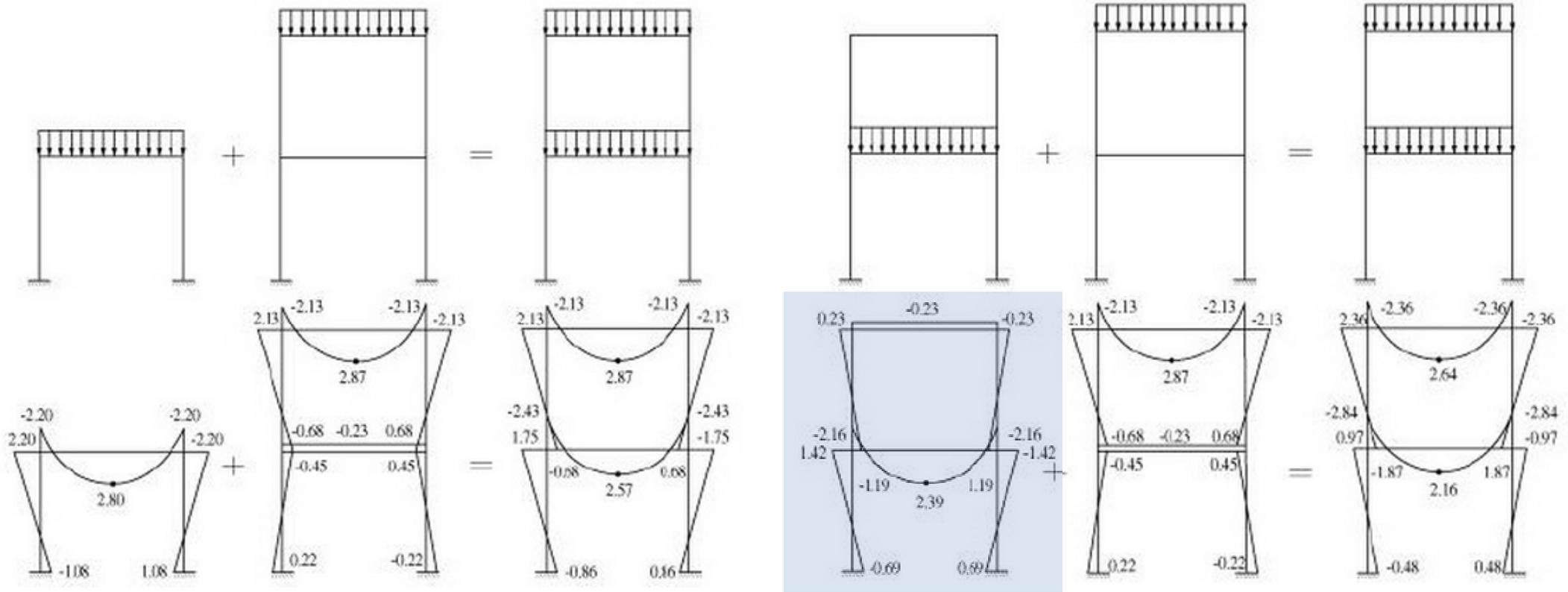


Time-dependent
Material testing

**Construction
stage analysis**



Construction Stage Analysis



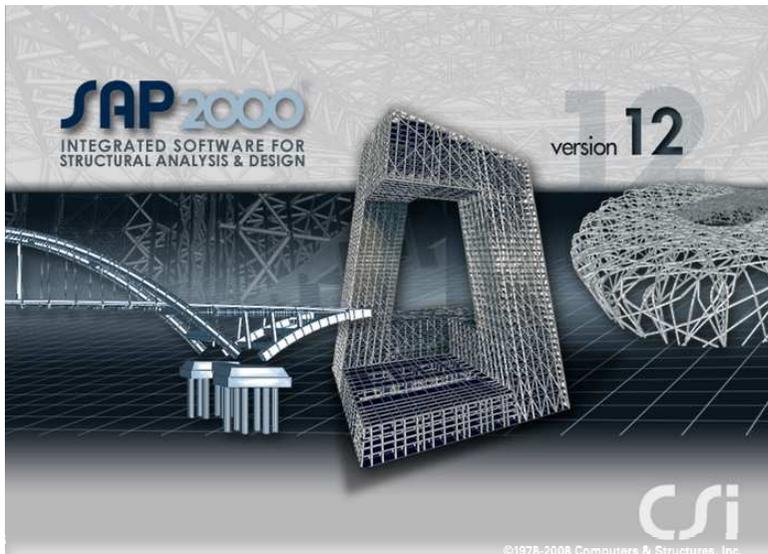
Construction Stage Analysis

Normal Structural Analysis

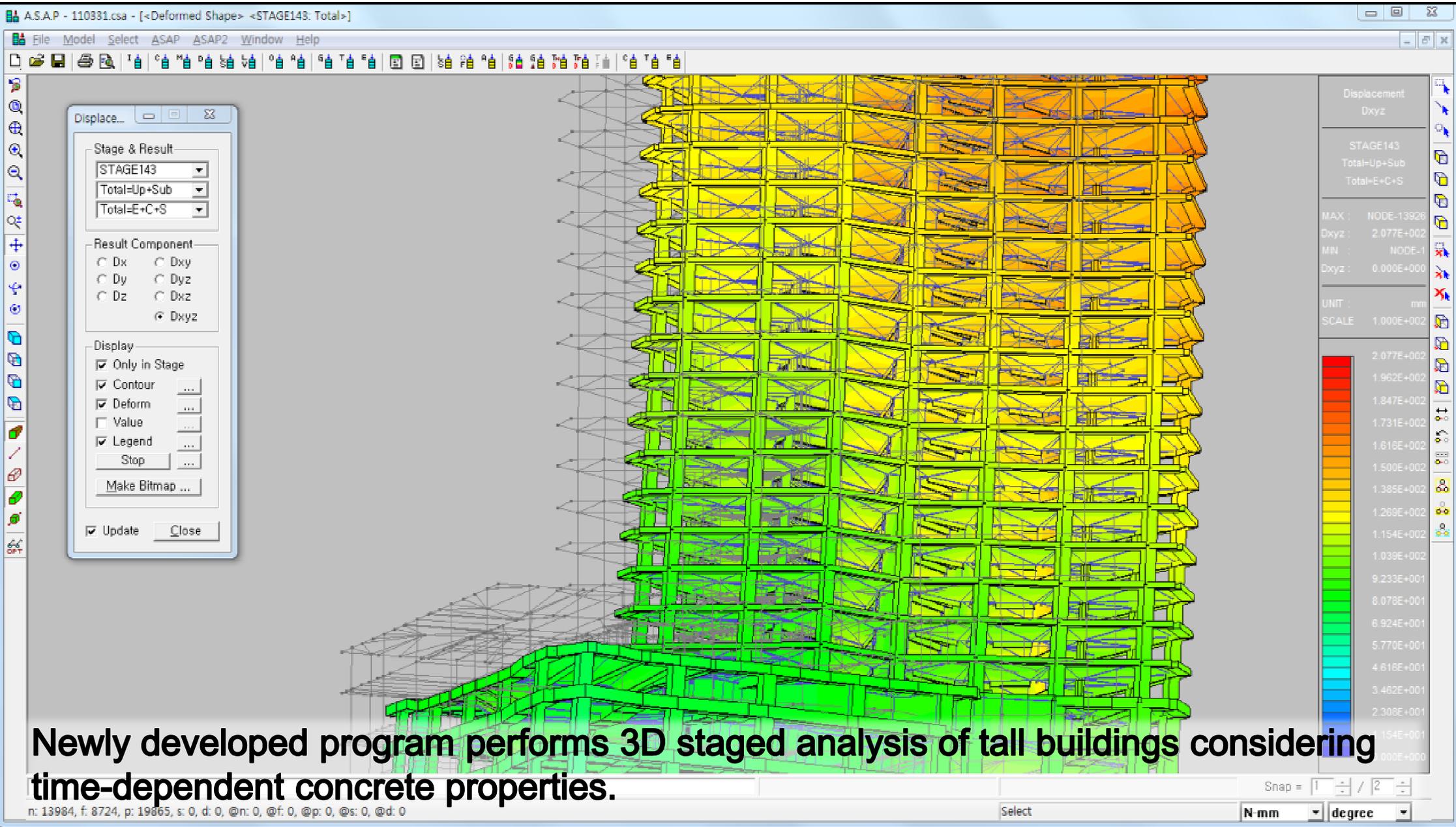
Construction stage analysis usually results in more member forces in lower levels and less member forces in higher levels.



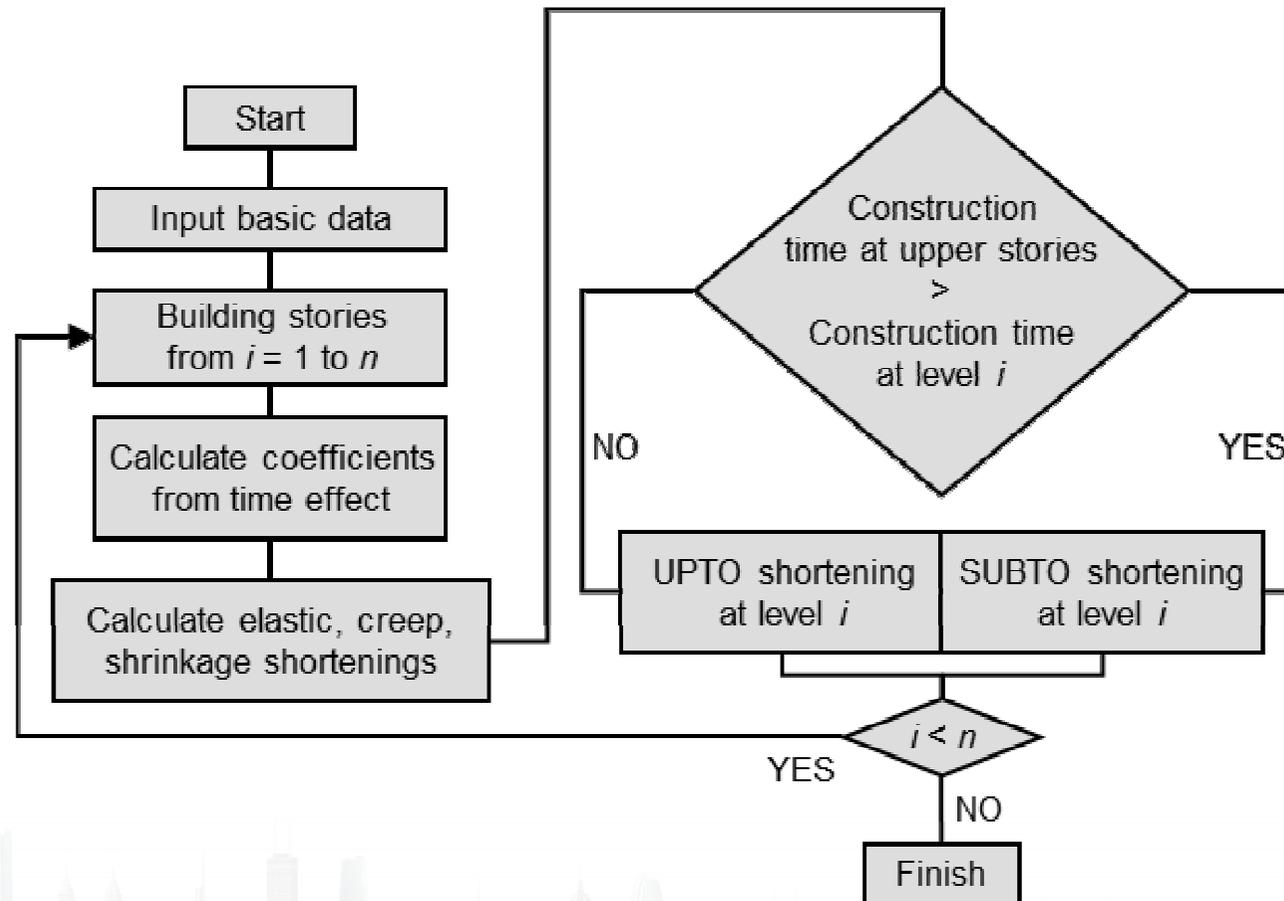
Commercial software



Several commercial software for structural analysis considering construction stage is on the market but they are not specially focused on tall buildings.

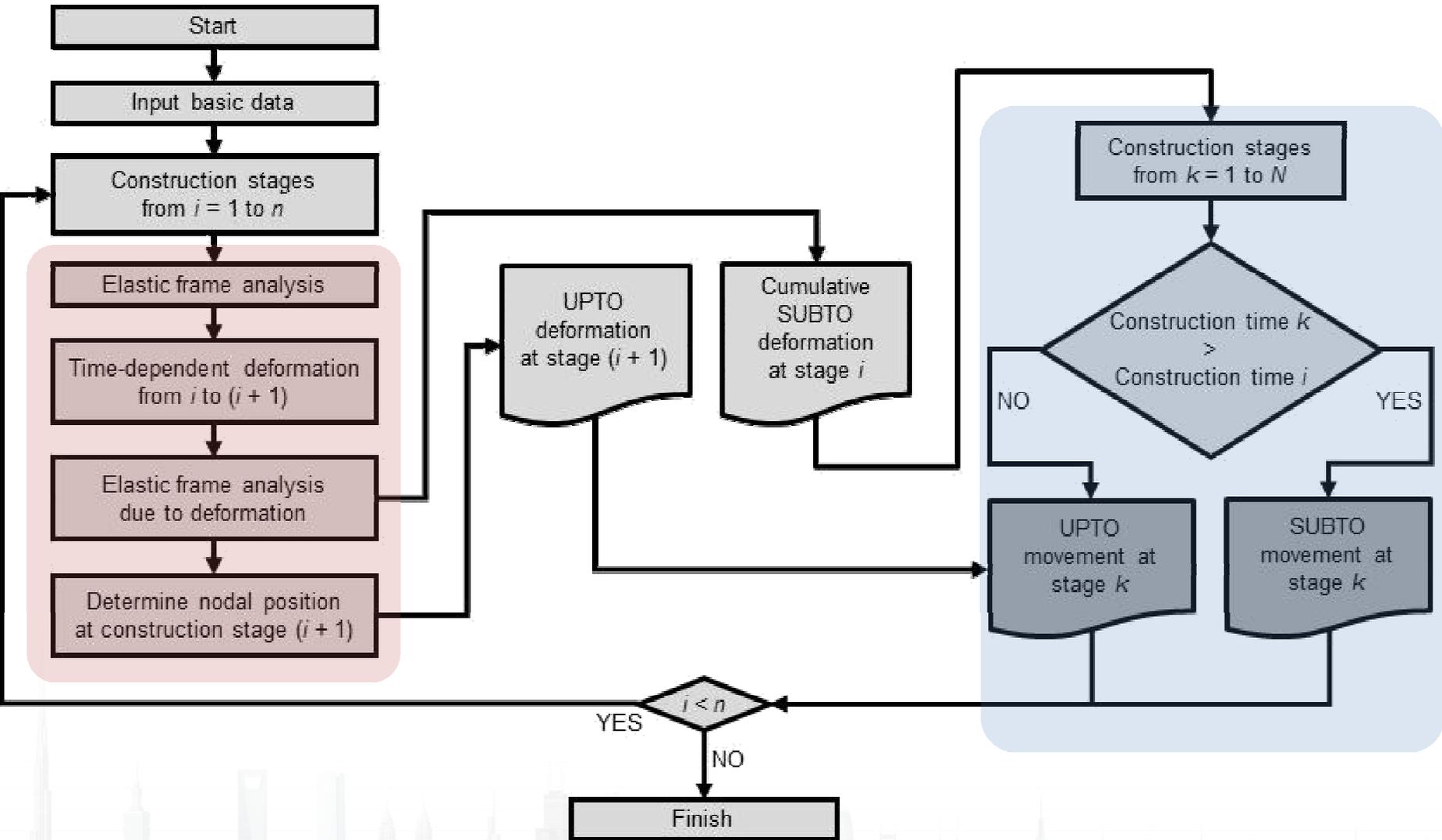


Algorithm in the past



In the legacy column shortening program, each of vertical members is evaluated for its individual deformation considering the construction of each story.

Revised algorithm



Newly developed software performs 3D analysis based on time-dependent creation and extinction of each node and can divided the movement by multiple target days.

Creep & Shrinkage

Define Material

Material 1 C35

Material Data

specified concrete strength 34,3233 N/mm2
 Mass Density 2400 kg/m3
 Curing Condition WATER
 Stone Type QUARTZITE
 Cement Type Type I
 Air Content (%) 2 %
 Water Content 205 kg/m3
 Cement Content 409 kg/m3
 Fine Aggregate percentage (%) 40 %
 Slump 75 mm
 Aggregate Content 1730 kg/m3

Additional Condition

Ambient relative humidity 65,00 %
 Volume to Surface Ratio 35 mm
 * When Analysis Running , be Calculated with Section Data

Show Result

Strength Creep Shrinkage Target Day 10000

5 PCA(Current Option)

- Compressive Strength at age of 28 days 39,6899 N/mm2
- Elastic Modulus at age of 28 days 31851,2 N/mm2
- Specific Creep Strain per unit Strength 75,586 E-6/N/mm2
- Nominal Ultimate Shrinkage Strain 780 E-6

6 ACI 209-R2

- Compressive Strength at age of 28 days 39,6899 N/mm2
- Elastic Modulus at age of 28 days 31851,2 N/mm2
- Nominal Ultimate Creep Coefficient 2,35
- Nominal Ultimate Shrinkage Strain 780 E-6

7 EUROCDOE 2

- Compressive Strength at age of 28 days 42,3233 N/mm2
- Elastic Modulus at age of 28 days 33915,4 N/mm2
- Nominal Ultimate Creep Coefficient 1,6388
- Dry Nominal Ultimate Shrinkage Strain 414,339 E-6
- Autogenous Nominal Ultimate Shrinkage Strain 60,8082 E-6

8 B3

- Compressive Strength at age of 28 days 42,6233 N/mm2
- Elastic Modulus at age of 28 days 33007,2 N/mm2
- Basic Creep Coefficients (q2, q3, q4) 128, 2,34, 7,4 E-6
- Drying Creep Coefficients (q5) 337 E-6
- Nominal Ultimate Shrinkage Strain 740,351 E-6

9 GL2000

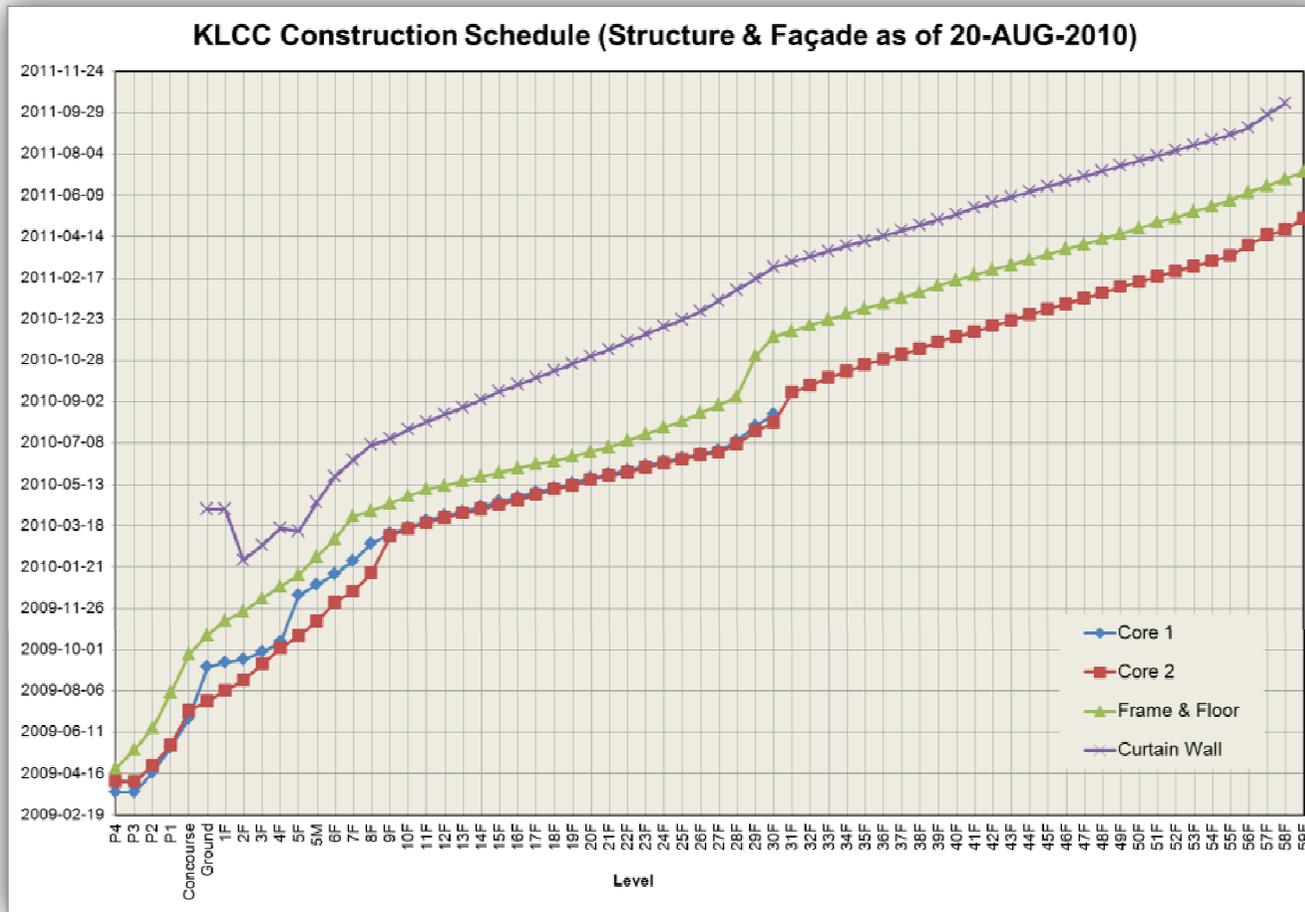
- Compressive Strength at age of 28 days 42,7556 N/mm2
- Elastic Modulus at age of 28 days 31616,7 N/mm2
- Basic Creep Coefficients 2, 1
- Drying Creep Coefficients (1st, 2nd) 1,35291
- Nominal Ultimate Shrinkage Strain 753,888 E-6

OK Cancel

Picture from Advanced courses in creep and shrinkage held in Udine, Italy, 2011.5.23~27

Several state-of-the-art material properties can be compared for their final results.

Construction Stages



Constructin Sc...

Construction Period

- Start Date: 2011-01-01

- Finish Date: 2012-04-01

- Current Date: 2016-01-01

Set Color of Date ...

Load Stage

Column: Define ...

	Date	Days
Steel	2011-01-01	0
RC	2011-01-01	0
Form Duration		0
Remove	2011-01-01	0

Apply to Selected Elements

Color Date Type

String Day Type

Set Date Automatically...

Set Date by Story...

Apply OK Cancel

Constructin Stage

No	Title	Date	Days	Story
1	STAGE1	11-01-01	0	B1
2	STAGE2	11-01-31	30	1F
3	STAGE3	11-03-02	60	2F
4	STAGE4	11-04-01	90	2F
5	STAGE5	11-04-08	97	2F
6	STAGE6	11-04-15	104	4F
7	STAGE7	11-04-22	111	5F
8	STAGE8	11-04-29	118	5F
9	STAGE9	11-05-06	125	6F
10	STAGE10	11-05-13	132	7F
11	STAGE11	11-05-20	139	9F
12	STAGE12	11-05-27	146	9F
13	STAGE13	11-06-03	153	10F
14	STAGE14	11-06-10	160	12F
15	STAGE15	11-06-17	167	12F
16	STAGE16	11-06-24	174	13F
17	STAGE17	11-07-01	181	15F
18	STAGE18	11-07-08	188	기계실 종결
19	STAGE19	11-08-07	218	17F
20	STAGE20	11-08-14	225	14F
21	STAGE21	11-08-21	232	17F
22	STAGE22	11-08-28	239	18F
23	STAGE23	11-08-04	246	20F
24	STAGE24	11-09-11	253	20F
25	STAGE25	11-09-18	260	23F
26	STAGE26	11-09-25	267	22F
27	STAGE27	11-10-02	274	23F
28	STAGE28	11-10-09	281	24F
29	STAGE29	11-10-16	288	26F
30	STAGE30	11-10-23	295	26F
31	STAGE31	11-10-30	302	29F
32	STAGE32	11-11-06	309	30F
33	STAGE33	11-12-06	339	31F
34	STAGE34	12-01-05	369	32F

1 STAGE1 11-01-01 0 B1

Add Delete Modify

Set Stage Automatically

Add Element Birth Day of RC

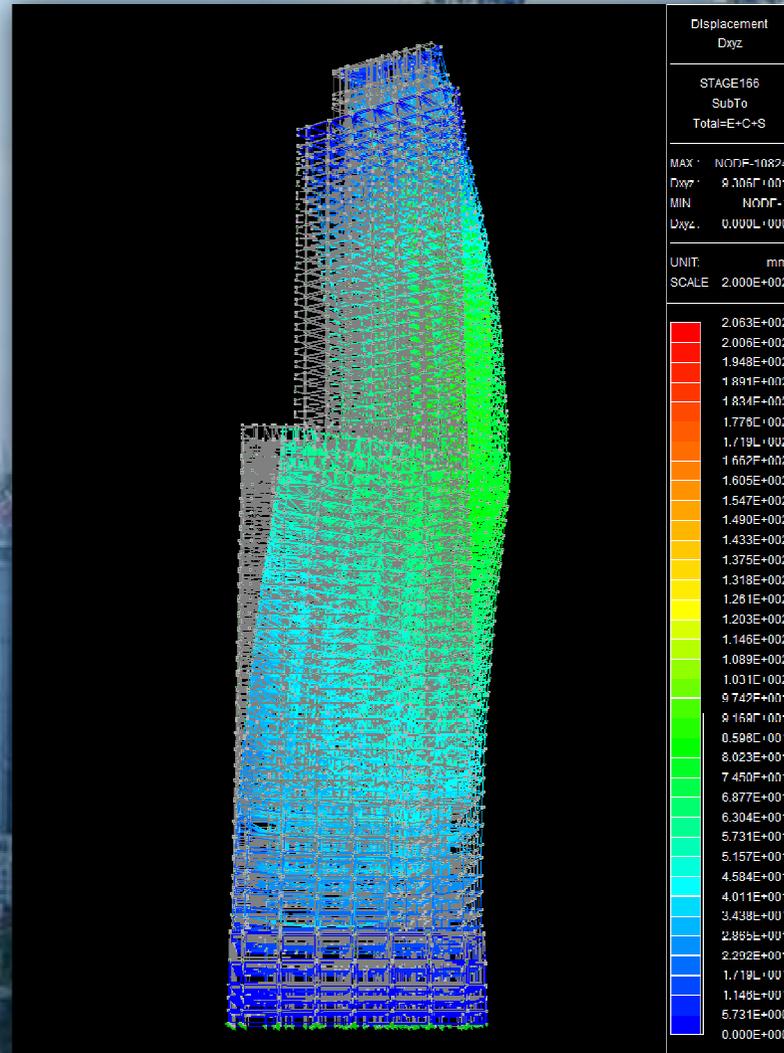
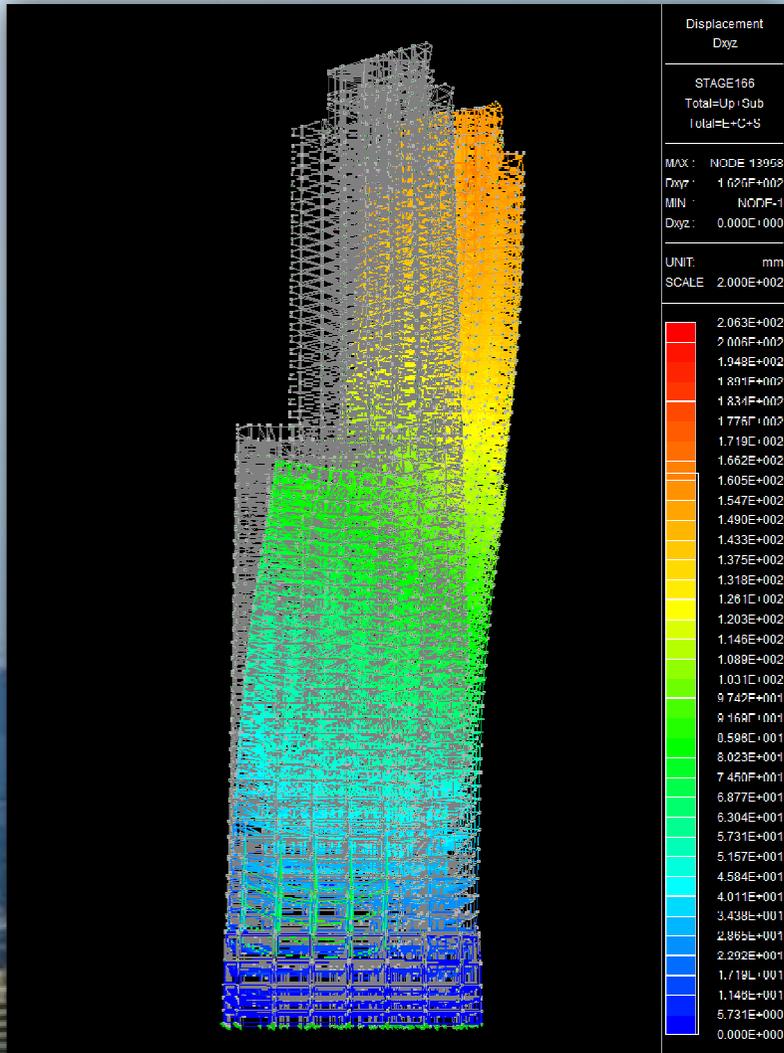
Add Form Removal Day of RC

Add Additional Loading Day

Set Stage

OK Cancel

Complex construction schedules including shoring schemes can be easily imported from tabulated ASCII file and important dates are chosen as analysis stages

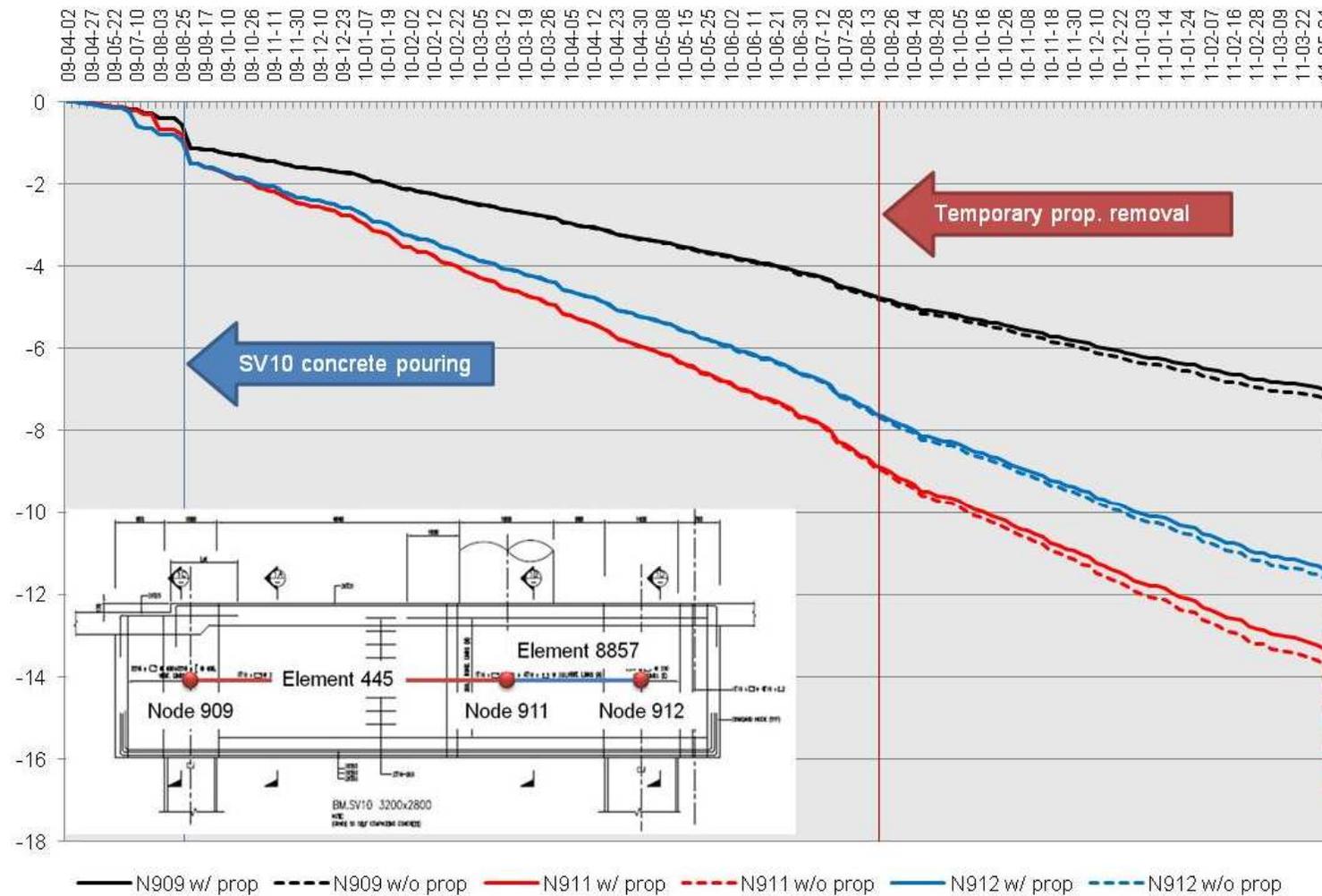


KLCC Tower Project



KLCC Tower in Kuala Lumpur is a 58-story eccentrically arranged tall building. Well-thought-out compensation was performed to prevent problems caused by movement

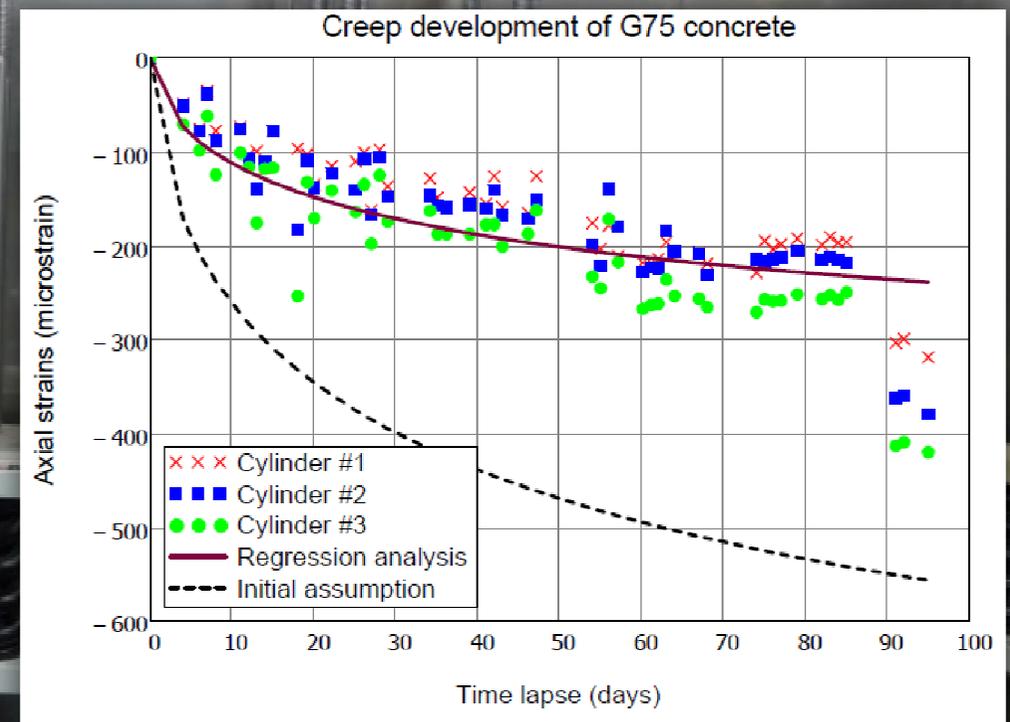
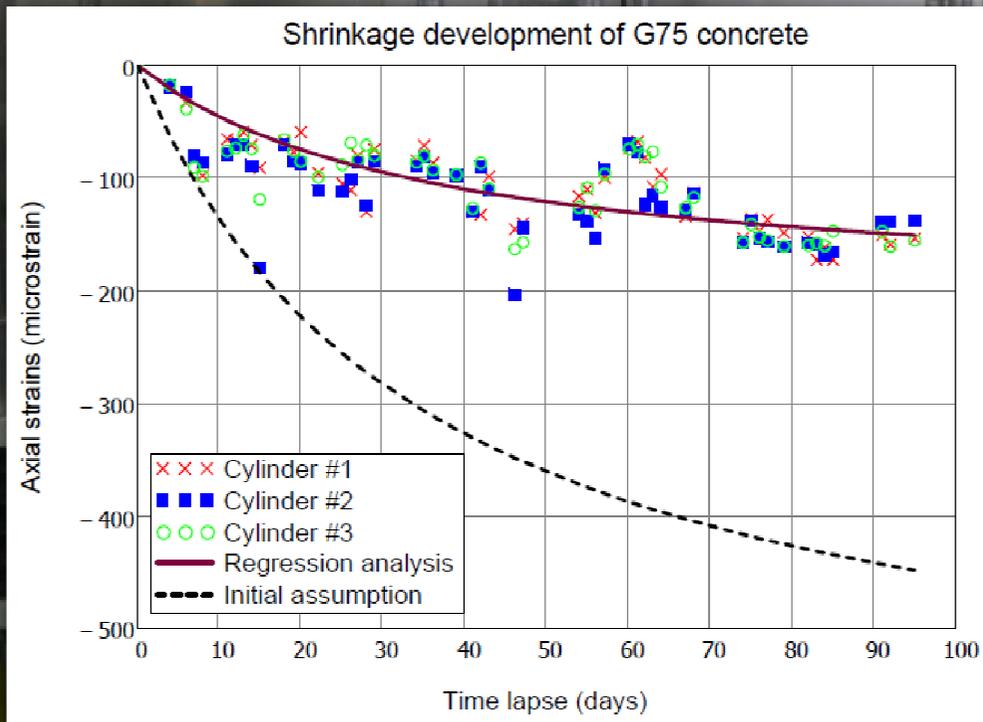
Vertical displacement of nodes in SV10 during construction



Deflections in Transfer Girder

The staged analysis of the transfer girder revealed the differences in member forces and displacement. Based on the result, the supports were removed after 1 month.

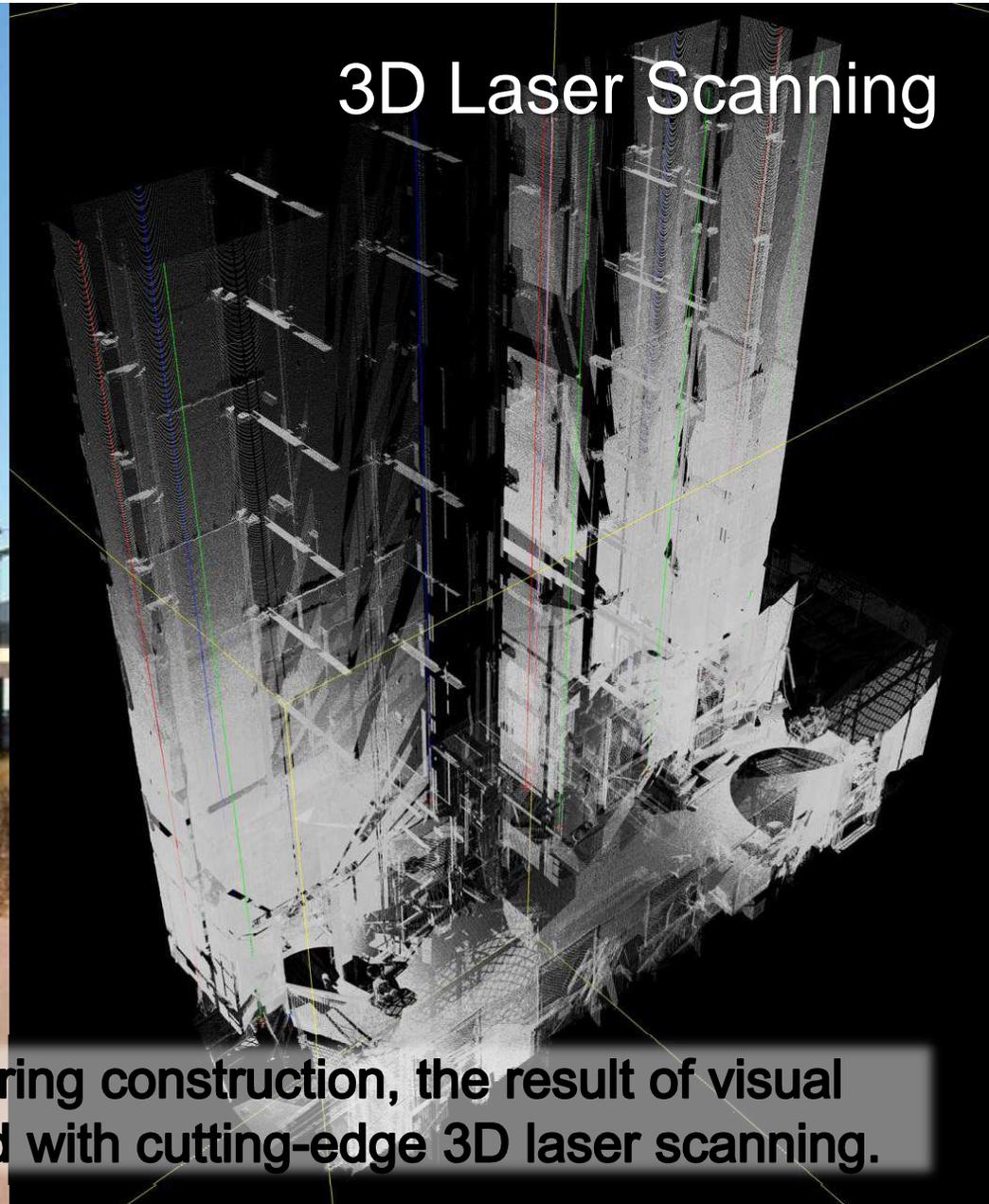
Creep & Shrinkage Test



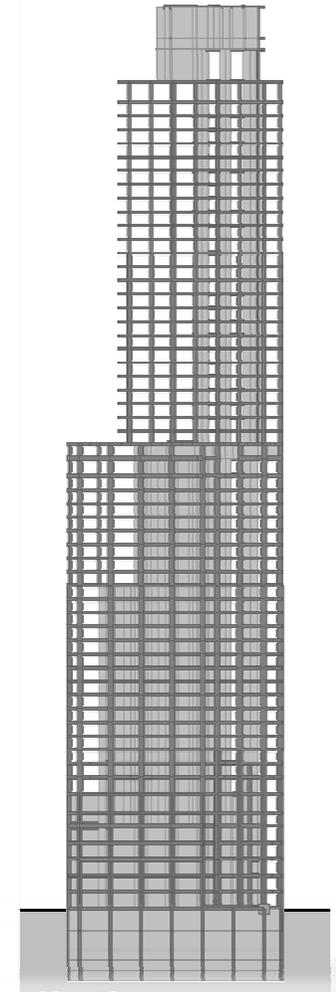
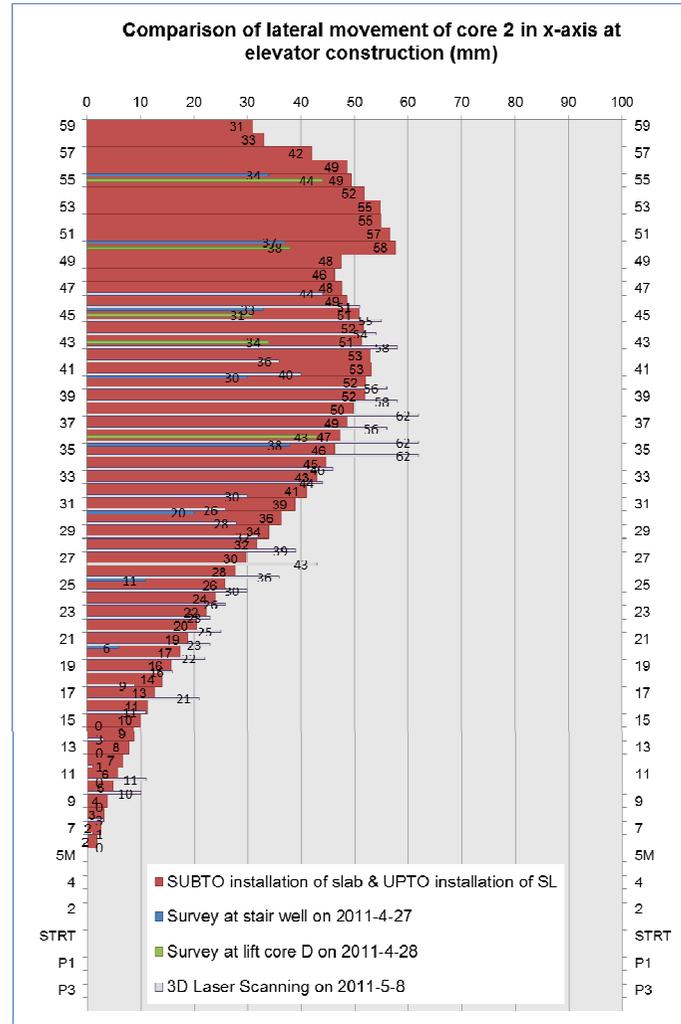
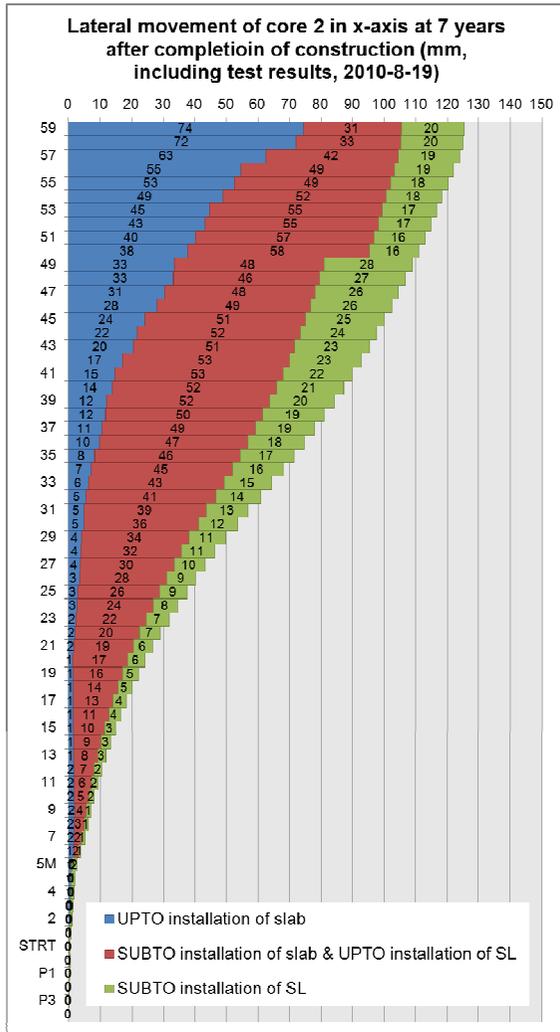
The building movement is refined after its initial prediction based on time-dependent laboratory material testing such as creep, shrinkage and modulus of elasticity.



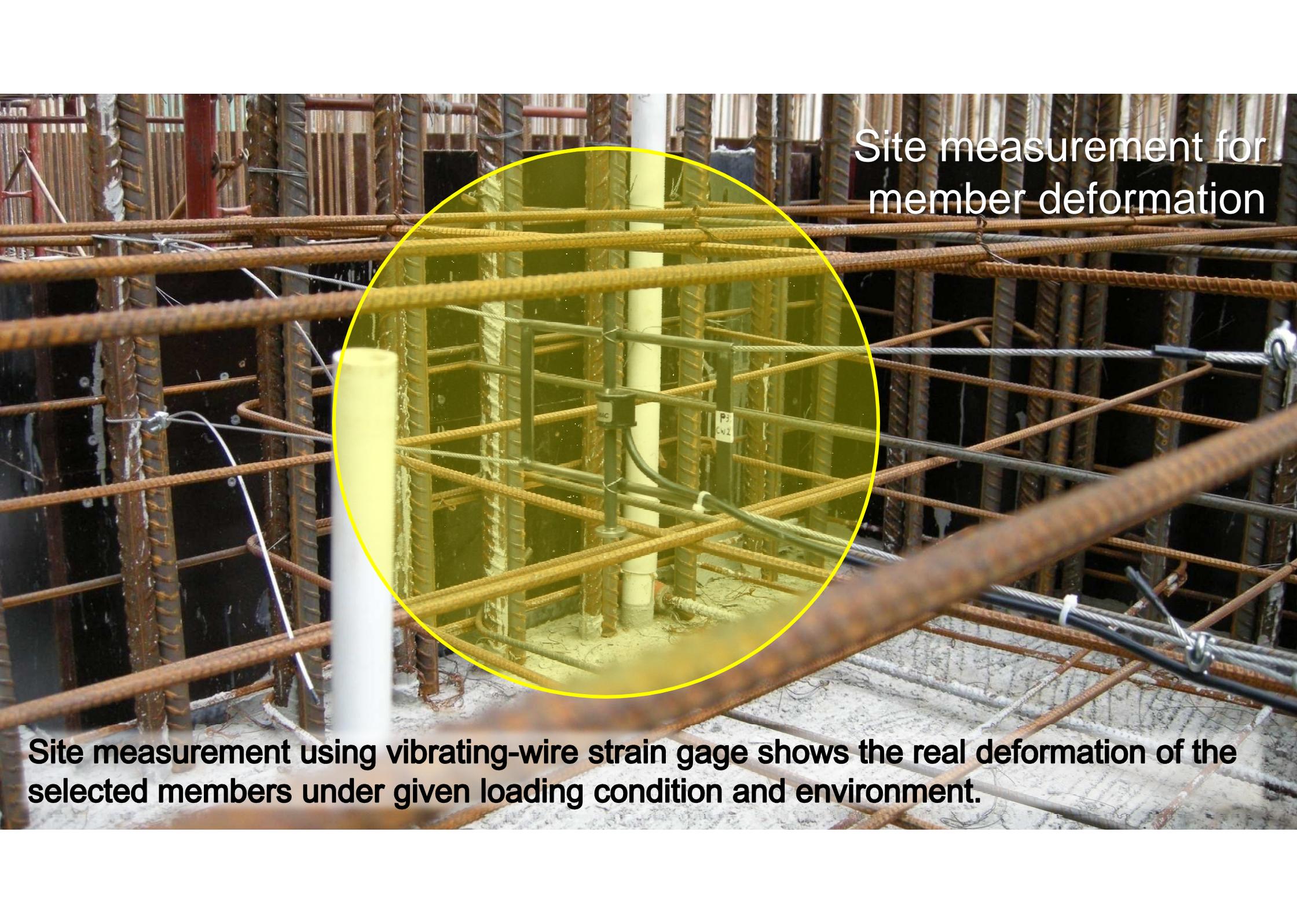
For better monitoring of building movement during construction, the result of visual survey by professional surveyor was combined with cutting-edge 3D laser scanning.



3D Laser Scanning



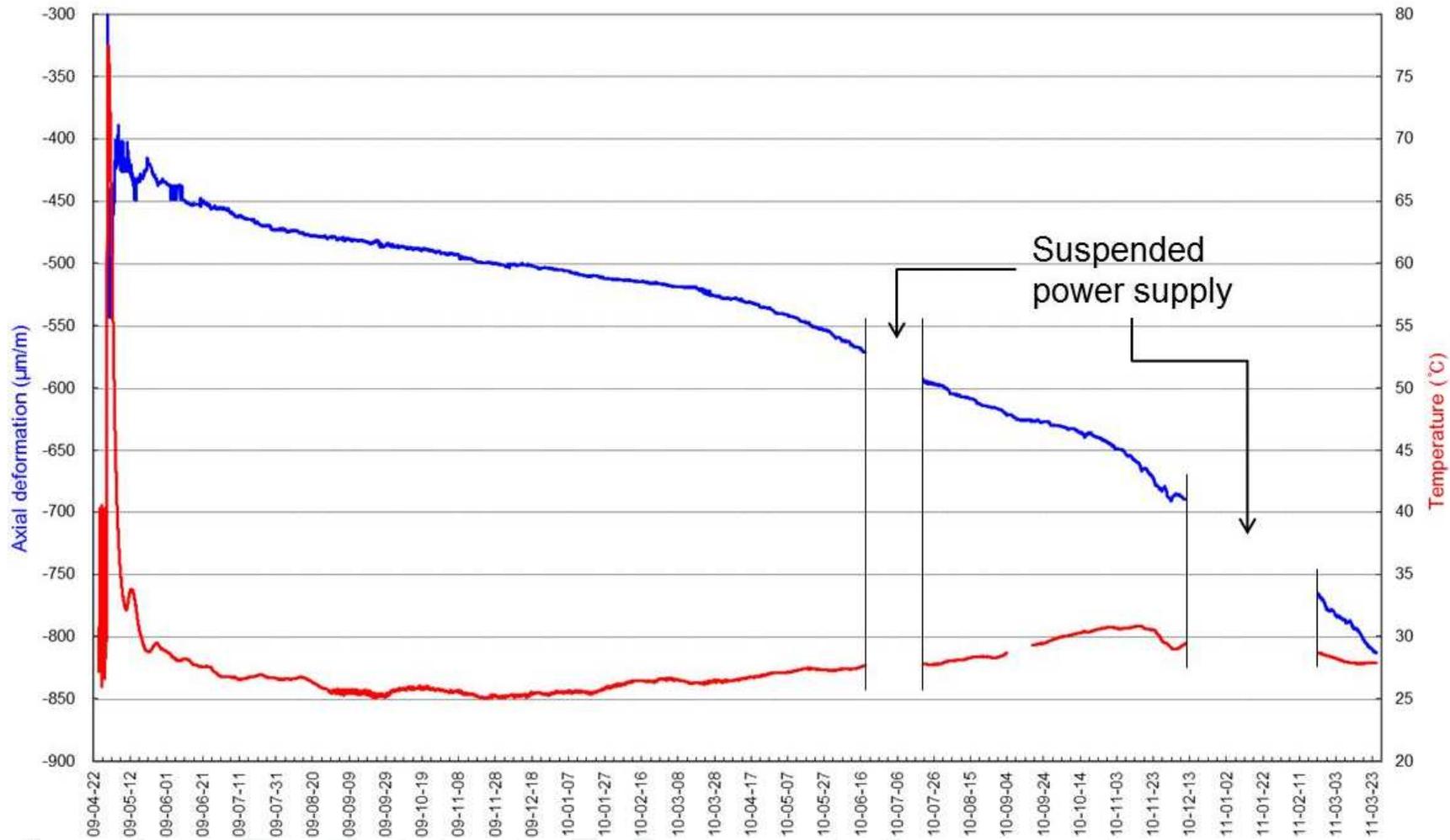
The result of prediction of lateral movement of lift core at time of lift installation was verified by both of visual inspection and 3D laser scanning.



Site measurement for member deformation

Site measurement using vibrating-wire strain gage shows the real deformation of the selected members under given loading condition and environment.

Example of measured shortening



Column shortening was continuously measured with the variation of temperature in this 2-year graph with some exceptions due to suspended power supply.

Thank You for Attention!!!

Taehun Ha

taehun.ha@gmail.com

